THE DEEPENING CYCLONE IN THE NORTHERN PLAINS STATES, MAY 1-4, 1955

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1. INTRODUCTION

On May 4, 1955, there was a surface Low with central pressure slightly below 980 mb. just north of Minot, N. Dak. (fig. 3). As far as May storms are concerned, this one was not of particularly unusual dimensions nor was the weather which accompanied it of spectacular significance, although the cold front which trailed back into central Texas did trigger a few tornadoes in Wisconsin and locally severe storms in Iowa [1]. Along with the intensification of this storm, a surge of warm air caused temperatures to the east of the storm to rise to the high 80's and low 90's as far north as Detroit, Mich.

The purpose of this report is to present a descriptive case study of this deepening storm, highlighting those aspects which the day-to-day forecaster has time to consider before making his prognosis of the situation. The National Weather Analysis Center (NWAC) prognostic charts for the period involved are presented (fig. 1), the synoptic sequence, surface and aloft, is discussed, and a few upper air aspects of this deepening storm are examined.

2. THE PROGNOSIS

The NWAC 30-hour surface prognostic chart which verified at 0030 GMT, May 4, and the accompanying 36-hour 500-mb. prognosis which verified at 0300 GMT, May 4, are shown in figure 1. A comparison of these two prognoses with the observed charts (fig. 3) shows that little of the storm's development was forecast. This is borne out by comparison of the verification scores for these charts with the scores for all others made during May (assuming all forecast situations were of equal difficulty). According to the NWAC verification system [2] in which the lower score is the better prognosis, the surface prognosis scored 83 compared with a May average of 63, incidentally, the best month of record in 8 years of verification. The 500-mb. prognosis scored[1] 72 with a May average of 55.

Even in retrospect it is not always a small job to determine why any given forecast failed. But the discussion in the sections which follow may serve to convince the reader that this was a difficult forecast to make. In presenting these NWAC prognoses it is the authors' intent merely to emphasize that there is some utility even in a poor prognosis. The detailed study of these prognoses and the further evaluation and examination of this forecast problem beyond that which follows are left to the reader.

[1] The 500-mb. verification system used by NWAC is based on gradient comparison similar to that used for the surface but in which it is assumed that the forecasting of west-east gradients is twice as difficult as forecasting the south-north gradients.

3. SYNOPTIC SEQUENCE AT THE SURFACE

At 0030 GMT, May 1, a weak, complex Low (with centers and fronts shown on figure 4) covered the United States from the Great Plains westward. A 1026-mb. High was centered north of Fort Wayne, Ind., with a moderate ridge extending from the Yucatan Peninsula to the Great Lakes, thence to Resolute, Northwest Territories. This ridge constituted a temporary blocking condition which was further indicated by a +1200-ft. 1000-500-mb thickness departure from normal centered between Lake Winnipeg and Lake Superior. Before breaking down, this block was effective in keeping low pressure systems confined principally to the western portions of North America.

By 1230 GMT, May 2 (fig. 2), the western half of the United States was still predominantly under the influence

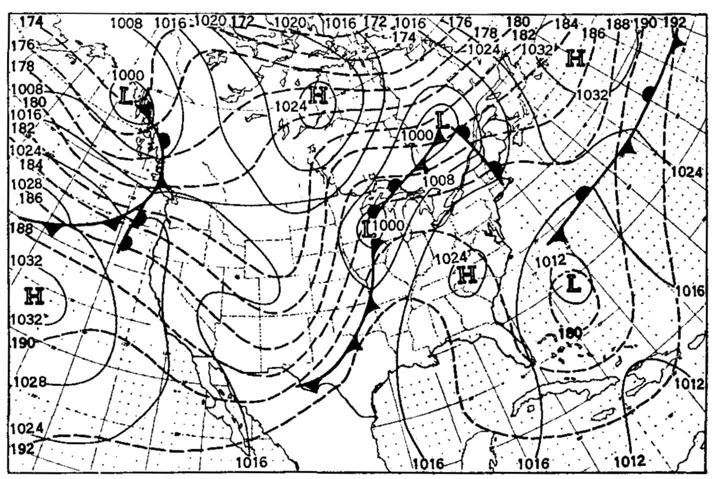

FIGURE 1.—30-hr. prognostic surface isobars (solid lines) with positions of fronts and centers for 0030 GMT, May 4, 1955; and 36-hr. prognostic 500-mb. contours (dashed lines) for 0300 GMT, May 4, 1955.

of low pressure with a 998-mb. center near Cheyenne, Wyo., showing signs of becoming better organized than it had been, as the block over Canada gave way rapidly. The northern portion of the ridge moved eastward and extended from New England to Yucatan. Little significant weather was evident. Fairly steady precipitation over central and southern California, less than one-half inch for the most part, had just about ceased. Meanwhile, continuous light rain had begun to fall over western Montana.

The surface pressure tendencies at that time were not at all indicative of the deepening about to occur. On the 1230 GMT surface chart for May 2 (fig. 2) there were few 3-hr. tendencies, within 500 miles of the center, which exceeded 1-mb. fall or rise. (Diurnal variations of pressure over the Northern Plains States are negligible at 1230 GMT.)

Thirty-six hours later (fig. 3) the maximum deepening had taken place over North Dakota. As the storm developed into a major depression, the effects of the rapid deepening were noted in all directions. The ridge over the eastern United States continued to rotate clockwise around a more or less stationary pivot in the Gulf of Mexico. Warm air flooded the western Great Lakes area as air some 40° to 50° F. colder flowed from Canada into the extreme northern part of North Dakota. (A few days later temperatures dropped below freezing in the upper Mississippi Valley and Great Lakes area as the storm sped to the northeast and was replaced by a cold Canadian High.) Except for the local storms noted in the Introduction, winds at the surface seldom exceeded 40 m.p.h. Rainfall totals in eastern Montana were generally from one-half to 1 inch, ranging to a maximum of 2.44 in. at Miles City [1]. In North Dakota smaller amounts, in most cases not exceeding one-half inch, were measured.

The pressure at 2130 GMT, May 4, was 979.9 mb. at Minot, N. Dak. Pressure rises of 5 to 8 mb. per 3 hr. occurred in North Dakota as the Low moved into the province of Manitoba.

4. SYNOPTIC SEQUENCE AT THE 500-MB. LEVEL

A summation of the long-wave features beginning 72 hours before 0300 GMT, May 4, follows: At 0300 GMT, May 1, there were long-wave troughs located at longitudes 70° W. 120° W., and 160° E. Midway between the two westernmost troughs there was a fastmoving short-wave trough. After 36 hours (fig. 2) there was relatively little change in the general features of the long-wave pattern. The amplitude of the troughs was not appreciable except over North America where the amplitude was between 1200 and 1500 miles. Because the wave lengths of the long waves were not too well adjusted for a stationary state, it now seems fairly obvious that the short-wave trough which moved into the Gulf of Alaska was of very considerable importance in readjusting the mean and immediate picture. At the time of prognosis its importance was either unrecognized or underestimated. By 0300 GMT, May 4 (fig. 3), the long waves were of roughly stationary length with their axes along longitudes 70° W., 130° W., and 175° E. During this readjustment the short-wave impulse which moved into the Gulf of Alaska forced warm air into western North America as the cold air associated with it pushed southward. The result was an acceleration of the short-wave trough out of the long-wave trough and into the Great Plains States, and a retrograde motion of the long-wave trough in the west.

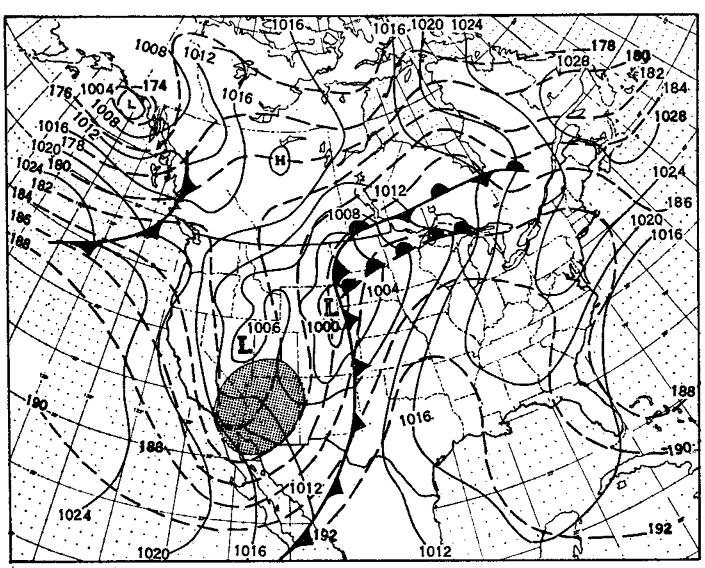

Figure 2.—Surface isobars (solid lines labeled in millibars) for 1230 GMT, May 2, 1955; and 500-mb. contours (dashed lines labeled in hundreds of geopotential feet) for 1500 GMT, May 2, 1955. Stippling represents principal region of cyclonic relative vorticity.

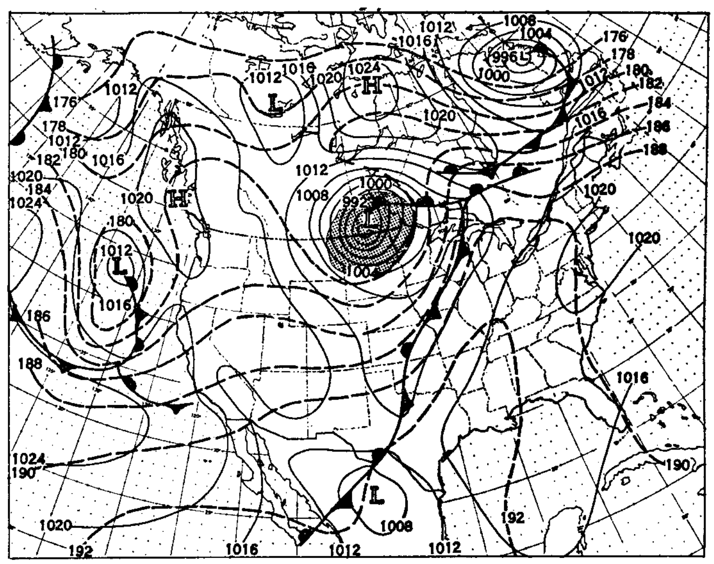

Figure 3.—Surface isobars (solid lines labeled in millibars) for 0300 GMT, May 4, 1955; and 500-mb. contours (dashed lines labeled in hundreds of geopotential feet) for 0300 GMT, May 4, 1955. Stippling represents principal region of cyclonic relative vorticity.

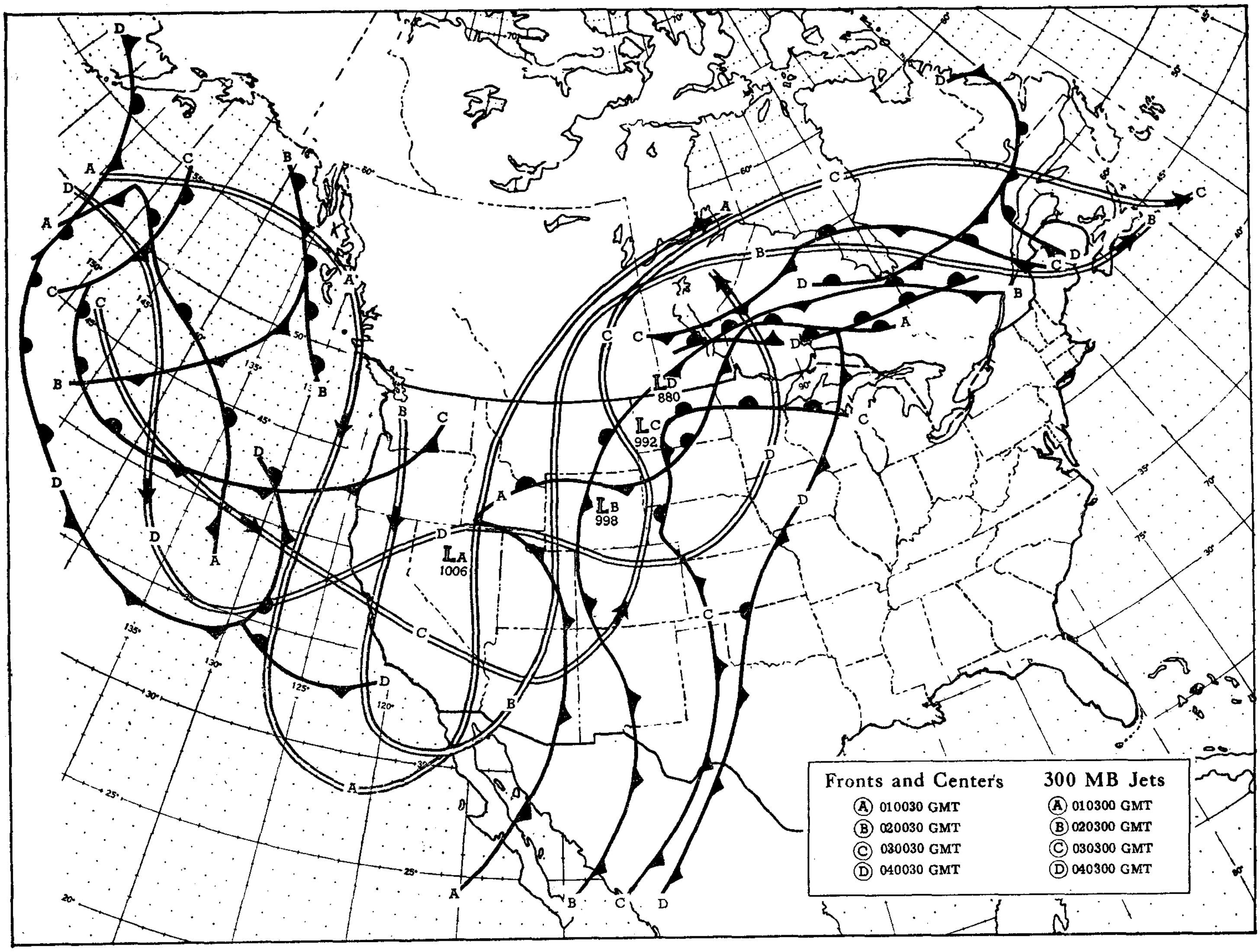

FIGURE 4.—Composite chart showing surface centers, surface fronts (barbed lines) and 300-mb. jets (double thin lines) for 0300 GMT, May 1–4, 1955.

Knowledge of the cyclonic relative vorticity field during this period from 0300 GMT, May 1, to 0300 GMT, May 4, would have been useful in making the prognoses had the proper long-wave implications been determined. A 500-mb. space-mean-flow chart which is often used to advect the vorticity field is not shown here. In this instance the 500-mb. chart is an acceptable approximation of the actual space-mean-flow for the period being discussed, and serves as a qualitative picture of the steering current. At 0300 GMT, May 1 (not shown), the cyclonic relative vorticity maximum lay generally over California north of 35° N. imbedded in the mean flow trough, with little flow across the vorticity field. The vorticity maximum first moved slowly eastward with the 500-mb. trough with no change in intensity. By 1500 GMT, May 2 (fig. 2), the vorticity maximum lay over Arizona and was approaching a region of strong 500-mb. (mean flow) contour gradient. Shortly thereafter the maximum of cyclonic relative vorticity turned northeastward into the strong south-southeasterly current. It then accelerated and intensified until by 0300 GMT, May 4 (fig. 3), it coincided with the circular 500-mb. Low.

The 500-mb. flow at 0300 GMT, May 1 (not shown), was characterized by a rather deep Low center just offshore from Santa Maria, Calif. After the strongest winds associated with the trough turned east and the plunging cold air reached its most southerly position, the Low recurved to the northeast. Thirty-six hours later, 1500 GMT, May 2 (fig. 2), the Low center, apparently much less well-defined than when it was offshore, was located in northwest Utah. In spite of its filling somewhat, the associated trough had lost none of its sharpness nor had there been any apparent warming in its core. The weakening ridge to the east still maintained some of its blocking characteristics, but showed further signs of weakening north of 50° N. as height falls ate into its northern perimeter. Isobars and isotherms were still essentially in phase, but with some hint of cold air advection beginning to appear in the southern and central Rocky Mountain area. By 0300 GMT, May 4 (fig. 3), the 500-mb. center had deepened approximately 400 ft. and showed a gradually accelerating northeastward movement. It then lay over the Manitoba–North Dakota border, not quite vertical with the surface center.

The 500-mb. departure from normal chart (fig. 5) for 36 hours before the surface and 500-mb. deepening, indicates a 200-600 ft. positive departure from normal which extended from Baffin Island to the Southern Plains States. A negative departure of equivalent magnitude was centered near Las Vegas, Nev. Another 600-ft. negative departure from normal in the Gulf of Alaska reflected the new short-wave trough moving from the northwest into the old long-wave position. It must have been apparent at the time the prognoses were made that this short wave would cause the cold air over Las Vegas to accelerate to the northeast. (Therein lies perhaps the basic error in the forecasts: the long-wave trough was taken eastward bodily, instead of bringing in a fast-moving short wave.) In 36 hours (fig. 6) the 500-mb. negative departure had raced north-northeast to North Dakota while the Gulf of Alaska cold pool plunged southward to reinforce the former long-wave trough. The trough associated with the deepening storm had definitely acquired short-wave dimensions and characteristics. The long-wave trough became readjusted to a mean position somewhat farther west than it had been.

Another aspect of the 500-mb. level is that of the 24-hr. height changes (not shown here). Thirty-six hours before 0300 GMT, May 4, there was a moderate katallobar of about 400 ft. over southeastern Colorado. There was an anallobar of more than 400 ft. just off the southern California coast. Thus over a distance of some 600 miles there was a west-east tendency gradient of about 1000 ft. This indicated that the meridional flow was not yet deteriorating. By 0300 GMT, May 4, the katallobar had increased to 800 ft. as it moved into North Dakota, not inconsistent with the deepening which extended from the surface to high levels. A breakdown of the strong meridional flow was then imminent since the anallobar center moved into southeastern Colorado causing the tendency gradient to become more south to north, indicative of a more westerly flow at 500-mb.

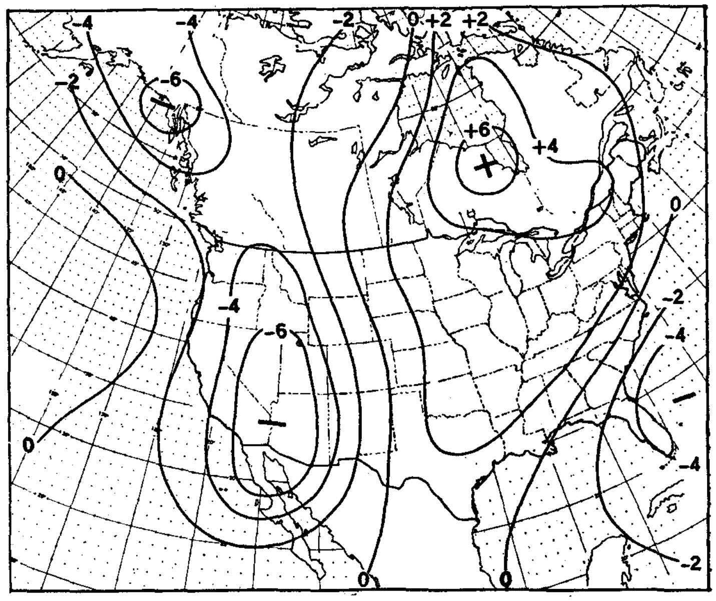

FIGURE 5.—500-mb. departure from normal chart (labeled in hundreds of geopotential feet) for 1500 GMT, May 2, 1955.

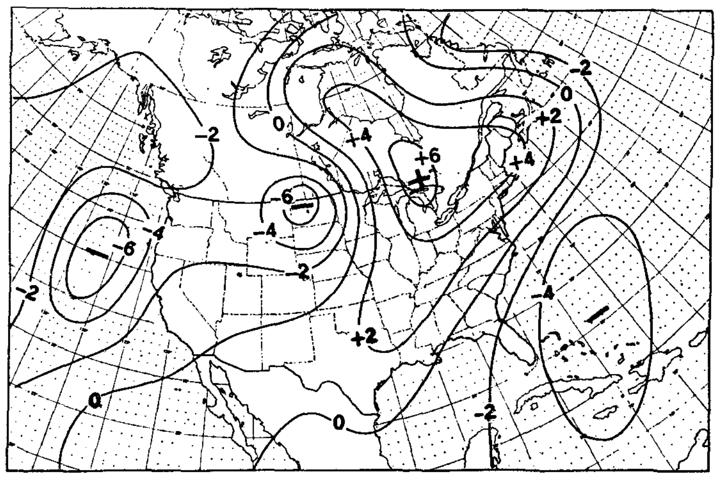

FIGURE 6.—500-mb. departure from normal chart (labeled in hundreds of geopotential feet) for 0300 GMT, May 4, 1955.

5. OTHER UPPER AIR ASPECTS

The Showalter Stability Index patterns (not shown) for the period involved were examined. It was thought that there might be some relationship between Stability Index and deepening. This one case study could hardly be representative in any event, but it is of interest to note that there were no indications of excessive instability, before the onset of deepening, which could be conclusively correlated with deepening. During the 48 hours preceding intensification there was an area of instability over the Plains States reaching roughly from the Canadian border to the Rio Grande River. More than anything else, the Stability Index delineated the cold frontal zone associated with this storm.

The behavior of the 300-mb. jet stream during the 72-hr. period before the storm reached its maximum depth (fig. 4) was not noticeably different from that described by Vederman [4]. Prior to the occlusion process the jet stream remained west and north of the surface centers and fronts. After the surface fronts occluded the 300 mb. jet position was south and east of the surface center. At 0300 GMT, May 2, the 300-mb. jet stream (fig. 4) was horseshoe shaped over the States west of 110° W. with a maximum speed in excess of 100 knots over central California and another maximum of the same speed over central Arizona. In 24 hours the jet maximum which had been in

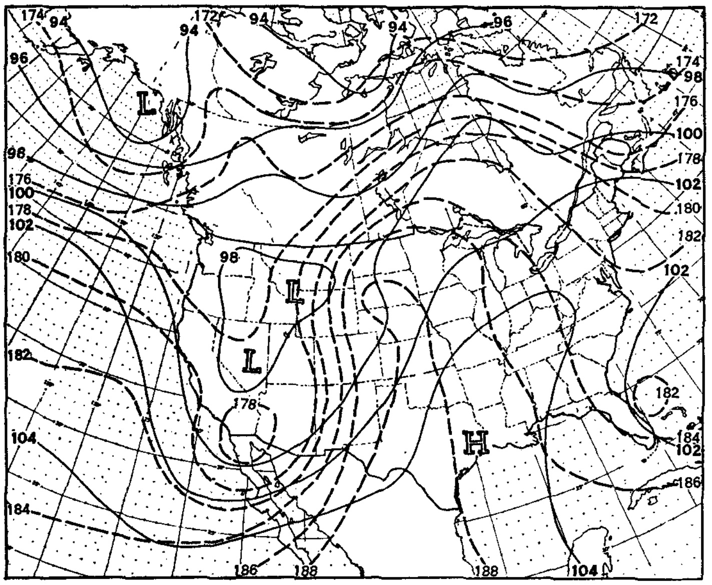

FIGURE 7.—700-mb. contours (solid lines labeled in hundreds of geopotential feet) for 1500 GMT, May 2, 1955; and 1000–500-mb. thickness contours (dashed lines labeled in hundreds of geopotential feet) for 1500 GMT, May 2, 1955.

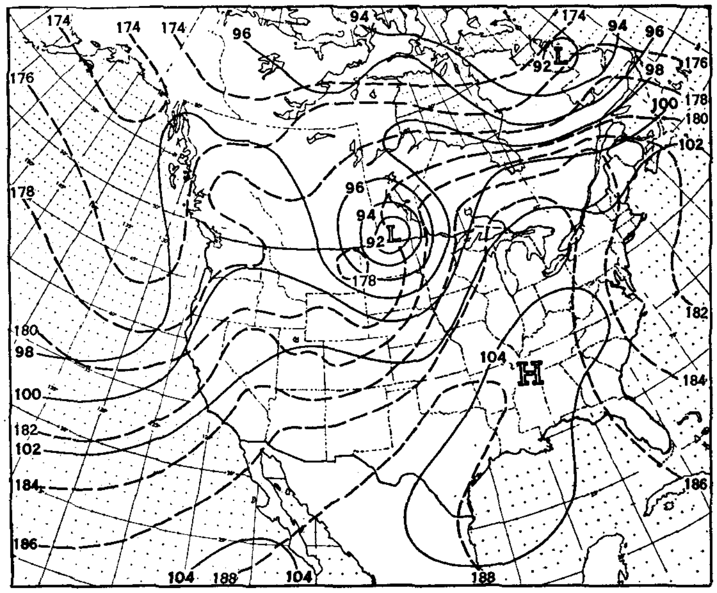

FIGURE 8.—700-mb. contours (solid lines labeled in hundreds of geopotential feet) for 0300 GMT, May 4, 1955; and 1000–500-mb. thickness contours (dashed lines labeled in hundreds of geopotential feet) for 0300 GMT, May 4, 1955.

California disappeared while the Arizona maximum moved downstream to Colorado with an increased maximum wind of at least 150 knots. By 0300 GMT, May 4, the jet maximum had moved into the Northern Plains States with little change in intensity.

The 1000–500 mb. thickness pattern for 1500 GMT, May 2 is shown in figure 7, superimposed on the 700-mb. chart for the same time. Using this chart to make a qualitative estimate of the advection likely to occur, it appears that weak to moderate cold air advection could have taken place from the southern Rocky Mountains to Nebraska and the Dakotas. Weak warm air advection was indicated on the west side of the 700-mb. trough. There was little other warm air advection of any consequence apparent in connection with this storm except far to the east between International Falls, Minn., and James Bay. Therefore, from considerations of advection alone, it was unlikely that deepening would occur. In addition to no apparent warm advection, thickness values in advance of this system were already more than 600 ft. above normal. The configuration of thickness contours did approach one of the deepening models proposed by Sutcliffe and Forsdyke [3]. In figure 7 the thickness contours are generally S shaped from Hudson Bay to the cold pocket over Yuma, Ariz. It takes little imagination to modify this picture into one of the cyclonic thermal involution types. Cyclogenesis would then be expected to proceed near the inflection on the west side of the thermal ridge portion of the involution. An examination of the thickness chart for 0300 GMT, May 4 (fig. 8) shows that thickness values which had been 1000 ft. below normal over California and Arizona were rapidly modified so that by the time of rapid deepening those thicknesses were only 200 ft. below normal with a negative departure from normal of some 500 ft. over northern Wyoming.

In summation, the 1000–500-mb. thickness change during the period prior to 0300 GMT, May 4, amounted to a decrease of approximately 400 ft. in North Dakota. This alone would have caused a rise of 16 mb. at the surface, assuming no change at the 500-mb. level. However, there was a fall of about 800 ft. at 500 mb., 400 ft. of which was canceled out by the 1000–500-mb. thickness decrease. There remained then about 400 ft. of falls at the 500-mb. level which was responsible for a 16-mb. fall at the surface.

6. CONCLUSION

It was the purpose of this study to examine a few general aspects of this deepening May storm and to try to throw some light on those phases which were poorly forecast. Ex post facto arguments have fairly obvious shortcomings, but it is felt that such arguments are worthwhile as long as they are used in trying to gain a better understanding of the forecast situation instead of retrospectively in trying to show how the prognoses should have been made. If only one crisp comment on the prognoses were allowed, the authors would be compelled to state that the long-wave features and modifications thereof had been underestimated.

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CORRECTION

MONTHLY WEATHER REVIEW, vol. 83, No. 4, page 94: In reference 14 to the paper by Newstein, the number and month of issue of the *Review* should be changed to No. 9, Sept. 1954.

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